Research Paper | Medical Science | E-ISSN No : 2454-9916 | Volume : 3 | Issue : 3 | Mar 2017

A GRAPH THEORETICAL APPROACH TO IDENTIFY MORPHOLOGICAL VARIATIONS IN HARD AND SOFT TISSUES OF THE FACE IN CLASS 1 AND CLASS 2 MALOCCLUSION

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ABSTRACT

In this article we demonstrate approaches, models and methods from the graph theory universe and we discuss ways in which they can be used to reveal hidden properties and features of a network. This network profiling combined with knowledge extraction will help us to better understand the biological significance of the system. Network analysis has been applied recently to orthodontics to detect and visualize the most interconnected clinical, radiographic, and functional data pertaining to the orofacial system. In particular, by considering phenotypic, functional, and radiographic characteristics it has been shown that different kinds of dentofacial malocclusions correspond to different network structures. During the diagnostic process to establish the objectives, strategies, priorities and sequences of treatment, the orthodontist has to identify and locate the critical points of malocclusion.

The craniofacial region can be regarded as a complex system that grows and remodels itself following an intricate network of auxologic forces, distortive processes and/or compensatory mechanisms. The aim of this study is to show how "network thinking" and network modelling leads to a systemic analysis of standard diagnostic data under a different perspective. This study was undertaken to determine whether graphically significant differences exist in facial skeletal patterns among groups of cases presenting ANGLE CLASS I and CLASS II malocclusions. Class I subjects exhibited few highly connected orthodontic features (hubs), while Class II patients showed a more compact network structure characterized by strong co-occurrence of normal and abnormal clinical, functional, and radiological features. The topology of the dentofacial system obtained by network analysis could allow orthodontists to visually evaluate and anticipate the co-occurrence of auxological anomalies during individual craniofacial growth and possibly localize reactive sites for a therapeutic approach to malocclusion.

INTRODUCTION

A system of elements that interact or regulate each other can be represented by a mathematical object called a network. The decomposition of large networks into distinct components, or modules, has to be regarded as a major approach to deal with the complexity of large biological networks. A motif refers to a group of physically or functionally connected components (nodes in graph) that work together to achieve the desired biological function. These organized sets of interactions are capable of local ordering, function, process information, and presumably act as regulators of growth and development in determining auxologic choices between homeostasis and plasticity. Our understanding of malocclusions and how best to treat them are hampered by the complexity of the craniofacial system in which they are manifested. Treatment outcomes for Class I and Class II malocclusion patients are dependent on multiple factors including growth characteristics, facial morphology, environmental factors, direction and magnitude of corrective forces, treatment timing and duration, and patient's compliance. By applying Graphs analysis we identify some functional modules among orthodontic nodes. These modules correspond to groups of tightly interrelated features and presumably constitute the key regulators of plasticity and the sites of unbalance of the growing dentofacial Class I and Class II systems.

GRAPH THEORY AND DEFINITIONS

To introduce the basic concepts of graph theory, we give both the empirical and the mathematical description of graphs that represent networks as they are originally defined in the literature. If we want to understand a complex system, we first need to know how its components interact with each other. In other words we need a map of its wiring diagram. A network is a catalog of a system's components often called nodes or vertices and the direct interactions between them, called links or edges.

A graph G can be defined as a pair (V, E) where V is a set of vertices representing the nodes and E is a set of edges representing the connections between the nodes. We define as E = {(i, j)| i, j Î V} the single connection between nodes i and j. In this case, we say that i and j are neighbours. A multi-edge connection consists of two or more edges that have the same endpoints. Such multi-edges are especially important for networks in which two elements can be linked by more than one connection. In such cases, each connection indicates a different type of information. Through networks, the growing craniofacial system can be modelled as an aggregate structure of a variety of agents in which the clinical (radiographic, functional, etc.) characteristics can be transformed into nodes, and the relationships between these nodes are referred to as links. Transferring the network approach to orthodonticscan enable the identification of some general rules governing the progression of the craniofacial system.

OBJECTIVE

The aim of this study is to apply conjunctly statistical analysis with network tools and methodologies to Class I and Class II malocclusion features' longitudinal (i.e. time varying) data sets in order to uncover the systemic importance of such features and to individuate the possible emergence of features' subset driving the orofacial development of Class I and Class II malocclusions.

MALOCCLUSION

A malocclusion is a misalignment or incorrect relation between the teeth of the two dental arches when they approach each other as the jaws close - Coined by Edward Angle.

DIAGNOSIS

ANGLE'S CLASSIFICATION OF MALOCCLUSION

ANGLE Class I: NEUTROOCCLUSION

Molar Relationship: The mesiobuccal cusp of the maxillary first permanent molar occludes with the mesiobuccal groove of the mandibular first permanent molar.

Canine Relationship:- The mesial incline of the maxillary canine occludes with the distal incline of the mandibular canine. The distal incline of the maxillary canine occludes with the mesial incline of the mandibular first premolar.

Line of Occlusion: ALTERED in the maxillary and mandibular arches.

- Individual tooth irregularities (crowding/spacing/other localized tooth problems).
- Inter- arch problems(open bite/deep bite/cross bite)

ANGLE Class II: DISTOOCCLUSION

Molar relationship: The molar relationship shows the mesiobuccal groove of the mandibular first molar is DISTALLY (posteriorly) positioned when in occlusion with the mesiobuccal cusp of the maxillary first molar.

Canine Relationship: The mesial incline of the maxillary canine occludes ANTERIORLY with the distal incline of the mandibular canine. The distal surface of the mandibular canine is POSTERIOR to the mesial surface of the maxillary canine by at least the width of a premolar.

Class II Malocclusion has 2 subtypes to describe the position of anterior teeth:
- Class II Division 1: The maxillary anterior teeth are protruded.
- Class II Division 2: The maxillary anterior teeth are retroclined.

MATERIALS AND METHODS

We randomly selected a group of 30 Angle Class I and 30 Angle Class II malocclusion division. The participants were selected on the basis of normal growth,no

history of orthodontic treatment, and completeness of records. To characterize the patient population, we recorded 13 clinical, anatomic, functional, and radio graphic features.

INCLUSION CRITERIA

1. Full set of permanent dentition excluding third molars.
2. No functional displacement of the mandible during opening and closing.
3. No history of orthodontic treatment or orthognathic surgery.
4. No congenital missing, cleft or other congenital craniofacial problems.
5. Good medical history

Skeletal parameters

1) SNA (°)- Sella-Nasion to A Point Angle- 82 degrees

2) SNB (°)- Sella-Nasion to B Point Angle-80 degrees

3) ANB (°)- A point to B Point Angle-2 degrees

4) Occlusal Plane to SN (°)- SellaNasion to Occlusal Plane Angle-14 degrees

5) Go Gn-SN-SellaNasion to Mandibular Plane Angle-32 degrees

FIGURE 1- Cephalometric measurements used: 1-SNA (degree); 2-SNB (degree); 3-1.NA (degree); 4-1-NA (mm); 5-1.NB (degree); 6-1-NB (mm); 7-ANB (degree); 8- NS.Gn (degree); 9-SN.GoGn (degree)

Dental parameters:

1) U1- NA (degree)- Upper incisor to N - point A line-22mm

2) U1- NA (mm)- Upper incissor to N - point A line-4 degrees

3) L1- NB (degree)- Angle between lower Incisor to NB Line-25mm

4) L1- NB (mm)- Distance from lower Incisor to NB Line-4 degrees

5) SND- sella Nasion to D Point- 2 degrees

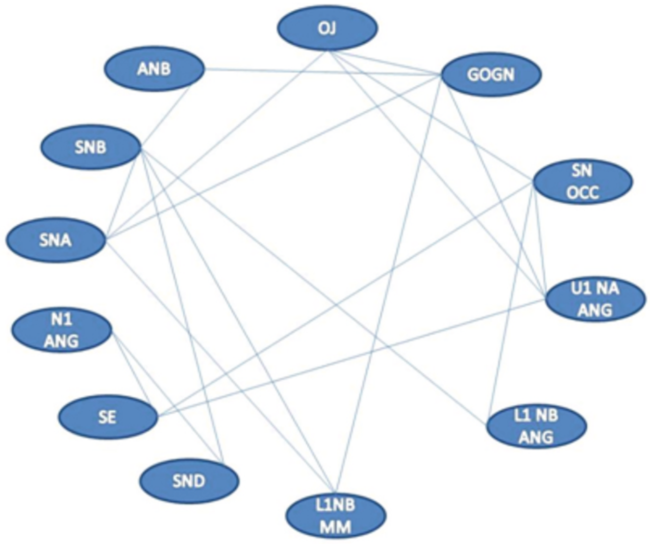
6) Overjet- distance between upper and lower anterior teeth-2mm

CORRELATION

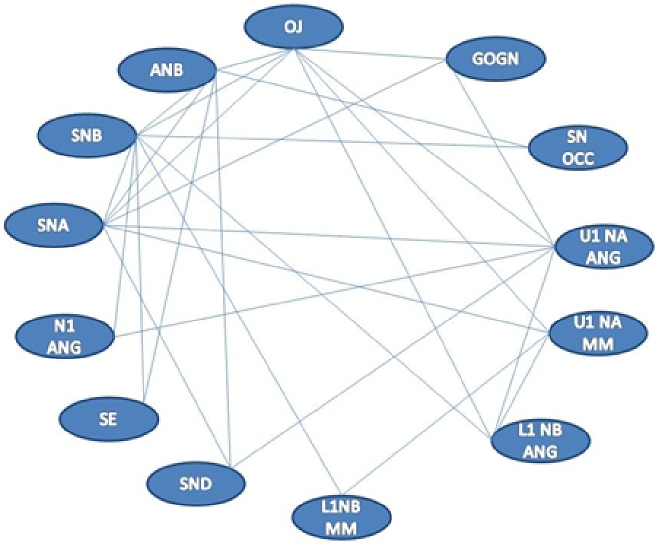
We constructed our networks from the Pearson product moment correlation coefficients between pairs of orthodontic features (correlation matrix). Each node corresponds to a feature, and each link represents the correlation between two features. The networks were built by fixing a (generally positive) threshold value T: two vertices (features) were connected (linked) if the correlation between them was closer than the fixed threshold value T. A link was discarded if two features co occurred in fewer than five patients. To prevent false positives, the significance of each correlation was also assessed by calculating the p-value for the null hypothesis with $p < 0.05$. Our networks therefore represent the significant correlations among features by discarding false positives and cases of poor statistics.

CLASS – I NETWORK

U1 NA mm feature is disconnected in this network



CLASS –II NETWORK



RESULT

Malocclusions rarely are a consequence of an abnormality in a single characteristic, but reflect perturbations in the complex structural and functional network that links soft tissues, bones, ligaments, articulations, and other biological tissues .Some characteristics of the dentofacial complex tend to have a greater effect than other characteristics. Some aspects tend to grow and acquire importance, while others diminish and play a negligible role in the development of the system. Network analysis provide vital informations about the most important nodes in a growing dentofacial complex. Networks have been visualised with the standard layout; the choice of filtering at $|rxy|>.0.20$ reduces the complexity of the system and permitted the identification of many characteristics just by visual inspection. In particular, it is very easy to identify bridge nodes, i.e. nodes whose absence would split the graphs in two or more separate parts. Motifs searches are potentially valuable tools to predict unknown interactions involving 3–5 nodes (rarely more than 6). These organized sets of interactions are capable of higher order functions (such as amplification), and hence probably represent the functional capabilities within the network. They provide balance between modules through signaling gates (i.e. negative feed forward motifs), favoring plasticity (open-gate configuration), or homeostasis (closed- gate configuration).

CONCLUSION

Orthodontic networks are able to represent the orofacial system in a visually intuitive way, making it possible to focus on the most closely connected features. These networks are presumably able to influence the treatment plan, perhaps even shortening it. Here, we present evidence that Class I and II malocclusions have different network structures. In the treatment of a new case, the value of every sign (feature) could be considered in the context of the network specific to that malocclusion. An important issue raised by calls for orthodontic network information is the potential integration of clinical data with radiographic and

functional data to better elucidate the etiology, occurrence, and progression of malocclusion. The structures of the correlation networks provide indications of the strength of interactions among orthodontic variables; the correction of interacting additive orthodontic problems could help shorten the treatment and perhaps increase its effectiveness.

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